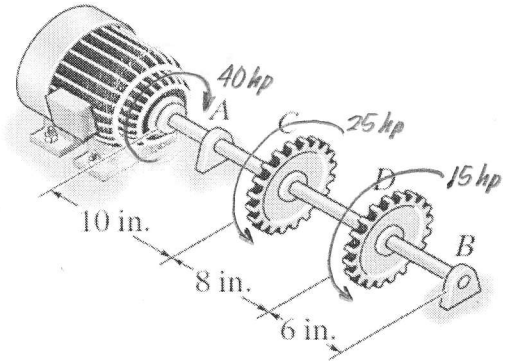
CME 260 – Mechanics of Materials
Exam #4 (03/02/2022)

Tech ID or Star ID: Grading

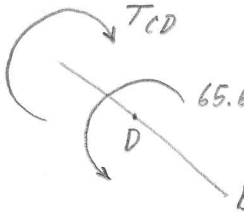
Do one of the two problems shown below (the second problem is on the back).
Show your work (you will not receive any credit if all you have is a final answer, right or wrong).

1. The motor shown below in the figure supplies (in a clockwise manner) 40 hp to the solid shaft as it rotates at 20 Hz. The 304 stainless steel shaft has a diameter of 1.5 inches and is supported on smooth bearings at A and B, allowing free rotation of the shaft. The gears C and D are fixed to the shaft and remove (in a counterclockwise manner) 25 hp and 15 hp, respectively. Determine the angle of twist of gear C with respect to gear D.



$P = 2\pi f T \rightarrow T = \frac{P}{2\pi f}$

@ D $\quad T_D = \dfrac{15\,hp\left(\frac{550\,ft\cdot lb}{s}\right)}{1\,hp} \Big/ 2\pi\,\frac{rad}{cycle}\;20\,Hz\left(\frac{1\,cycle}{s}\Big/\frac{1}{1\,Hz}\right) = 65.65\ lb\text{-}ft$ (4 pts)



$\Sigma M = 0, \; -T_{CD} + 65.65\ lb\text{-}ft = 0$

$T_{CD} = 65.65\ lb\text{-}ft$ (1 pt)

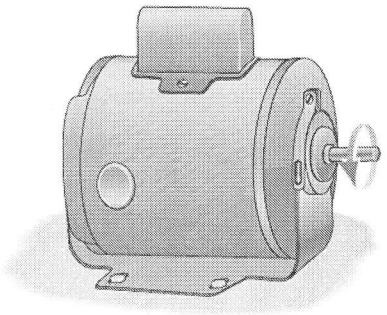
$\phi_{C/D} = \frac{TL}{JG}$

$= \dfrac{(65.65\ lb\text{-}ft)\left(\frac{12\,in}{1\,ft}\right)(8\,in)}{\frac{\pi}{2}(0.75\,in)^4\left(11\times10^6\,\frac{lb}{in^2}\right)}$

$= \boxed{1.153\times10^{-3}\ rad \quad \text{or} \quad 1.153\times10^{-3}\ rad\left(\frac{360^\circ}{2\pi\ rad}\right) = 0.0661^\circ}$

(5 pts)

2. The tubular shaft of the motor shown below has an outer diameter of 20 mm and a wall thickness of 2.5 mm and is made of a material with an allowable shear stress of τ_{allow} = 75 MPa. Determine the maximum allowable power (in kW) that can be supplied when the shaft is operating at 1,500 rpm.



$$\tau_{max} = \frac{Tc}{J} \rightarrow T = \frac{\tau_{max} J}{c}$$

$$T = \frac{\left(75 \times 10^6 \frac{N}{m^2}\right) \frac{\pi}{2} \left((0.010m)^4 - (0.0075m)^4\right)}{0.010\,m}$$

$$= 80.534\ N\text{-}m \quad (5\ pts)$$

$$P = 2\pi f T$$

$$= \left(2\pi \frac{rad}{rev}\right)\left(1{,}500 \frac{rev}{min}\right)\left(\frac{1\ min}{60\ s}\right)(80.534\ N\text{-}m)$$

$$= \boxed{12{,}650.2 \frac{N\text{-}m}{s} \text{ or } 12.65\ kW} \quad (5\ pts)$$